

What is claimed is:

CLAIMS

1. A method for providing thermal protection for an actuator in a haptic feedback device,
5 the method comprising:

determining an average energy in said actuator over a predetermined period of time; and

reducing the maximum allowable current level in said actuator if said average energy is determined to exceed a predetermined warning energy level.

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2. A method as recited in claim 1 wherein said average energy is determined over time by repeatedly moving an energy window by a predetermined timeslice and determining an average energy within said energy window after each of said movements.

3. A method as recited in claim 1 wherein said maximum allowable current level is reduced to a sustainable current level if said average energy reaches a maximum energy level allowed by said actuator, wherein said actuator can operate indefinitely without overheating at said sustainable current level.

20 4. A method as recited in claim 1 wherein said maximum allowable current level is reduced to a level below a sustainable current level if said average energy reaches a maximum energy level allowed by said actuator, wherein said actuator can operate indefinitely without overheating at said sustainable current level.

5. A method as recited in claim 1 further comprising raising said maximum allowable current level in said actuator after said maximum allowable current level has been reduced, if said average energy is determined to be below said predetermined warning energy level.

25 6. A method as recited in claim 1 wherein said maximum allowable current level is reduced gradually as a ramp function.

7. A method as recited in claim 6 wherein said maximum allowable current level is reduced as a function of the energy by which said predetermined warning energy level has been exceeded.

8. A method as recited in claim 1 wherein said average energy is approximated by determining a current in said actuator and basing said average energy proportionally on said current using a relationship $E = I^2R$.

9. A method as recited in claim 1 wherein said determining and said reducing are performed by a microprocessor local to said haptic feedback device and separate from a host computer communicating with said haptic feedback device.

10. A method as recited in claim 1 further comprising sensing current with a positive temperature coefficient (PTC) resettable fuse in a current path of said actuator, wherein said fuse opens to stop a flow of said current when said current increases to a fuse threshold level.

11. A method as recited in claim 1 wherein said actuator is a DC motor.

12. A haptic interface device in communication with a host computer implementing a host application program, said interface device manipulated by a user, the interface device comprising:

15 a sensor device operative to detect a manipulation of said interface device by said user, said sensor device outputting sensor signals representative of said manipulation;

at least one actuator operative to output force to said user; and

20 a controller coupled to said actuator and operative to determine an average energy in said actuator over a predetermined period of time as said actuator outputs said forces, and to reduce the maximum allowable current level in said actuator if said average energy is determined to exceed a predetermined warning energy level.

13. A haptic interface device as recited in claim 12 wherein said controller determines average energy over time by repeatedly moving an energy window by a predetermined timeslice and determining an average energy within said energy window after each of said movements.

25 14. A haptic interface device as recited in claim 12 wherein said controller reduces said maximum allowable current level to a sustainable current level if said average energy reaches a maximum energy level allowed by said method, wherein said actuator can operate indefinitely without overheating at said sustainable current level.

30 15. A haptic interface device as recited in claim 12 wherein said controller reduces said maximum allowable current level to a level below a sustainable current level if said average

energy reaches a maximum energy level allowed by said method, wherein said actuator can operate indefinitely without overheating at said sustainable current level.

16. A haptic interface device as recited in claim 12 wherein said controller raises said maximum allowable current level in said actuator after said maximum allowable current level has been reduced, if said average energy is determined to be below said predetermined warning energy level.

5 17. A haptic interface device as recited in claim 12 wherein said controller is a microprocessor local to said haptic feedback device and separate from said host computer.

10 18. A haptic interface device as recited in claim 12 further comprising a positive temperature coefficient (PTC) resettable fuse provided in a current path of said actuator, wherein said fuse opens to stop a flow of said current when said current increases to a fuse threshold level.

19. A haptic interface device as recited in claim 12 wherein said at least one actuator is at least one DC motor.

15 20. A method for providing actuator thermal protection for an actuator in a haptic feedback device, the method comprising:

determining an average energy in said actuator over a predetermined period of time;

reducing the maximum allowable current level in said actuator if said average energy is determined to exceed a predetermined warning energy level; and

20 raising said maximum allowable current level in said actuator if said average energy is determined to be below said predetermined warning energy level, wherein said maximum allowable current level can be raised to a maximum possible current that can drive said actuator.

25 21. A method as recited in claim 20 wherein said average energy is determined over time by repeatedly moving an energy window by a predetermined timeslice and determining an average energy within said energy window after each of said movements.

22. A method as recited in claim 20 wherein said maximum allowable current level is reduced to a sustainable current level if said average energy reaches a maximum energy level

allowed by said method, wherein said actuator can operate indefinitely without overheating at said sustainable current level

23. A method as recited in claim 20 wherein said maximum allowable current level is reduced gradually as a ramp function.
- 5 24. A method as recited in claim 20 wherein said maximum allowable current level is reduced as a function of the energy by which said predetermined warning energy level has been exceeded.

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